(12) UK Patent Application (19) GB (11) 2 394 178 (13) A

(43) Date of A Publication 21.04.2004

(21) Application No: 0223381.5

(22) Date of Filing: 09.10.2002

(71) Applicant(s):
Pulse Time Products Limited
(Incorporated in the United Kingdom)
York House, City Fields, CHICHESTER,
PO20 6FR, United Kingdom

(72) Inventor(s):
Richard John Willshire

(74) Agent and/or Address for Service:
Derek Jackson Associates
The Old Yard, Lower Town, CLAINES,
Worcs, WR3 7RY, United Kingdom

(51) INT CL[7]:
A61B 5/021 5/02

(52) UK CL (Edition W):
A5K K1
G1A AAMA AAMB AR7
G1N NEAX N30P1 N30P6

(56) Documents Cited:
EP 0181067 A3
US 6475153 B1
US 4562843 A
US 6511436 B1
US 4718428 A
US 20020055672 A1

(58) Field of Search:
UK CL (Edition W) **A5K, G1A**
INT CL[7] **A61B**
Other: **Online: JAPIO, WPI, EPODOC**

(54) Abstract Title: **Method of calibrating a blood pressure monitoring apparatus**

(57) A blood pressure measurement apparatus is calibrated by measuring the blood pressure of a living body using a sphygmomanometer and measuring a reference transit time 1, 3 of a blood pulse wave 9 travelling along a blood vessel pathway from the heart to a region remote from the heart, such as a finger. The arrival of the blood pulse wave 9 at the fingertip is detected by means of a photoplethysmograph This first measurement of blood pressure and transit time 1, 3 is used to generate a first calibration data point 61, 63. The region of the body remote from the heart is then raised and lowered from a position level with the heart and a transit time relating the lowered and raised positions is measured. The blood pressure difference is then calculated between when the region is raised or lowered. A transit time difference between the lowered and raised position transit time is calculated and a second data point 65, 73 is generated from the calculated blood pressure difference and transit time difference.

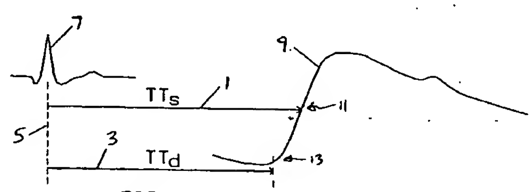

FIG. 1

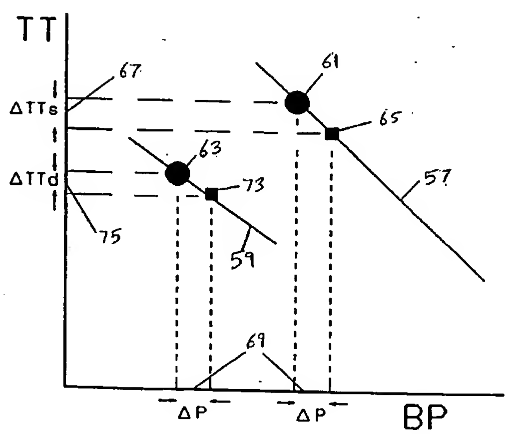

FIG. 7

GB 2 394 178 A

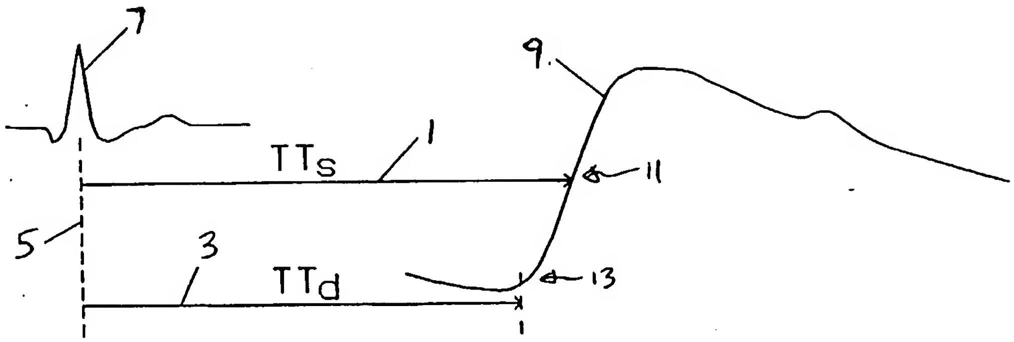

FIG. 1

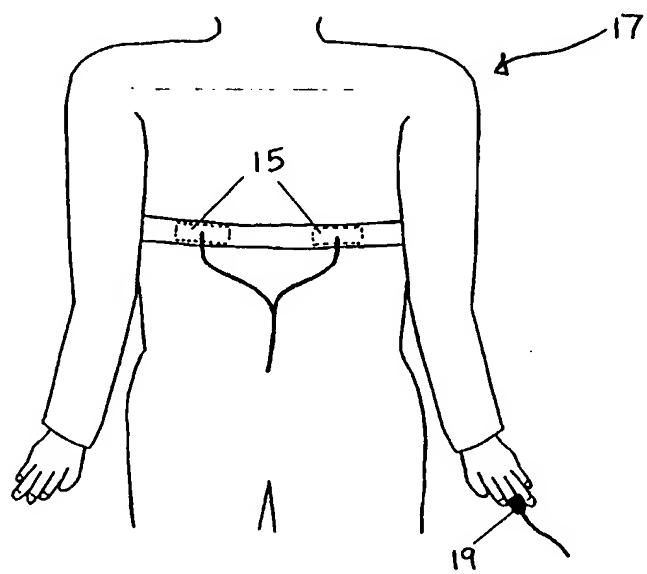

FIG. 2.

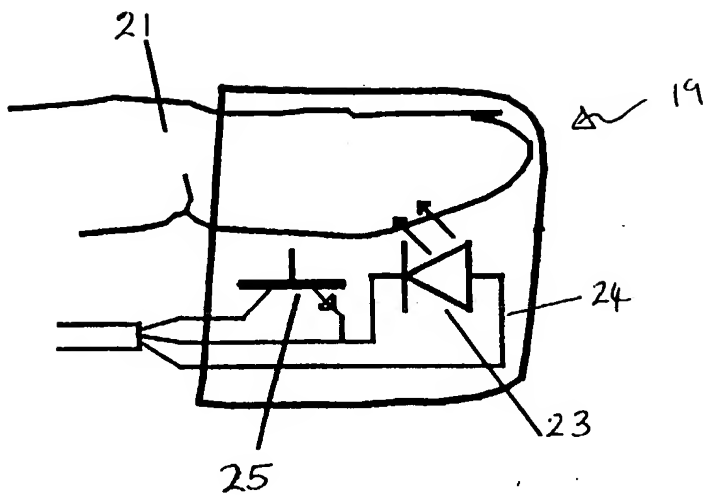

FIG. 3

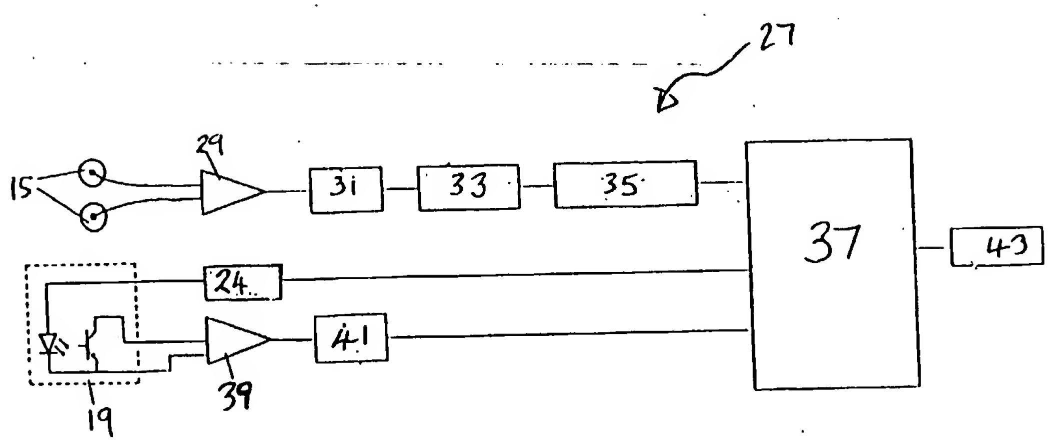

FIG. 4

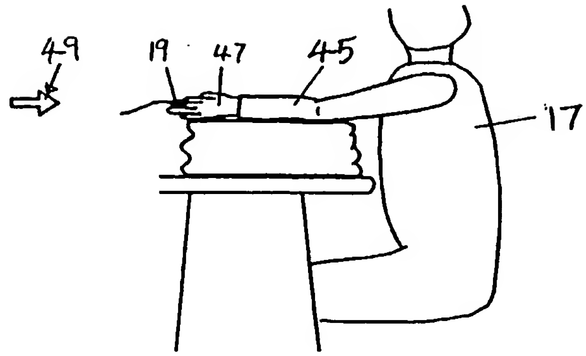

FIG. 5A

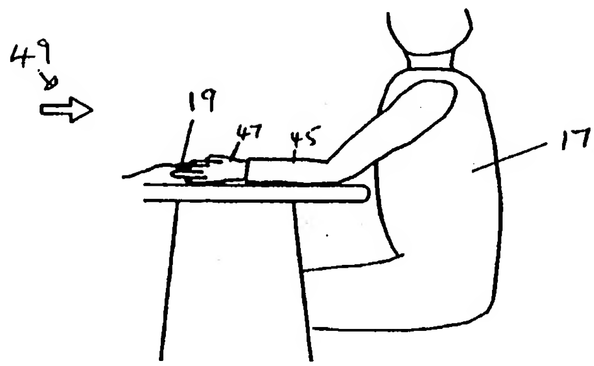

FIG. 5B

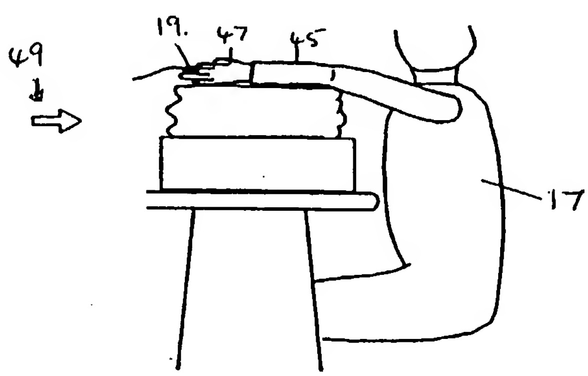

FIG. 5C

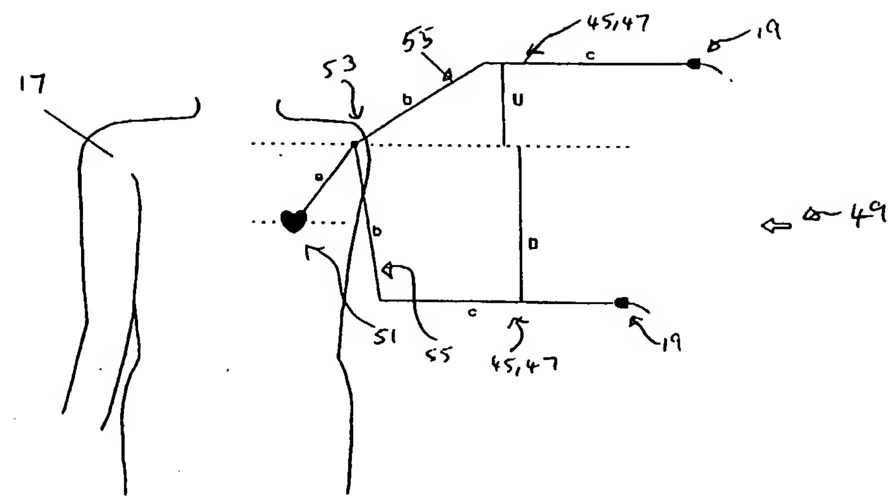
17
53
55
45,47
19
49
51
55
45,47
19

FIG. 6

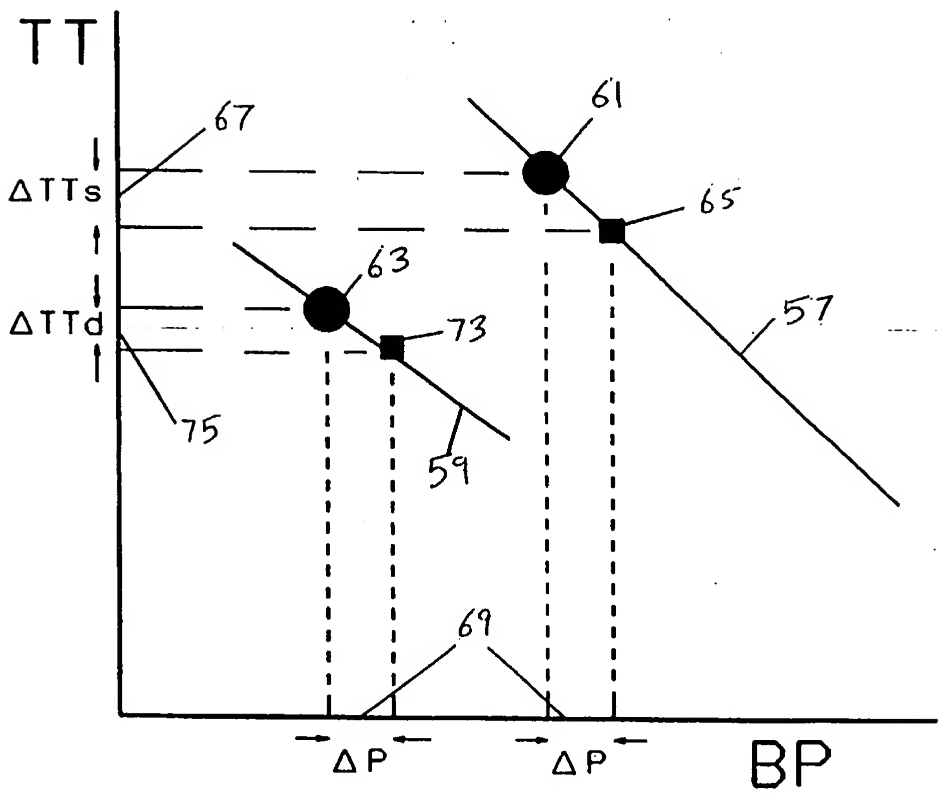
TT
67
ΔTTs
ΔTTd
75
61
65
63
73
57
59
69
ΔP
ΔP
BP

FIG. 7

2394178

METHOD OF CALIBRATING A BLOOD PRESSURE MONITORING APPARATUS

This invention relates to a method of calibrating a blood pressure monitoring apparatus, in particular the generation of at least one calibration line in order that blood pressure measurements of a living body can be determined.

Non-invasive methods of measuring the blood pressure of a living body, for example a human user, utilise, for example, a sphygmomanometer in the form of an inflatable cuff which fits around a portion of the user's body, for example an arm, wrist or finger. The measuring procedure involves the inflation of the cuff to a pressure higher than any blood pressure in the user, hence cutting off the blood supply, and then a slow release of the pressure over a period of time, for example 30 seconds. When the pressure of the cuff is equal to the user's highest blood pressure, blood will start to flow again past the cuff. This initial flow of blood occurs at the user's systolic blood pressure. As the pressure of the cuff decreases the blood pressure of the user will fluctuate between a level above the pressure in the cuff and a level below it. When all of the blood pressure fluctuations are above the pressure in the cuff,

the user's lowest blood pressure is identified. This is the diastolic blood pressure.

This process is uncomfortable, often noisy, and cannot be repeated very often before the tone of the flesh below the cuff degrades. Thus, while this process is useful for making isolated checks on blood pressure, it cannot be used to monitor blood pressure on every heart beat over a prolonged period of time.

It is known to a person skilled in the art that the pulse wave velocity of blood in the arterial system depends on the blood pressure existing within the arteries.

It has been found that the pulse wave transit time from the heart to a remote region of the body, for example, a fingertip, has a relatively linear relationship with systolic blood pressure over a relatively wide range of blood pressure. As systolic blood pressure increases, the transit time decreases.

Transit time is measured by obtaining an electronic trigger signal from an R-wave of an electrocardiograph (ECG) signal and timing from the detection of the electronic trigger signal to the arrival of a blood pulse wave detected, for

example, by a photoplethysmograph, at a remote region of the body, for example, a fingertip.

Transit time, as well as depending on blood pressure, also depends on other factors, for example, the size of the user's body and the state of the user's arteries. Therefore, to convert transit time to blood pressure for a particular user, calibration data must be generated for that user. This involves determining the individual's blood pressure/transit time relationship from many simultaneous measurements made with an occluding cuff type blood pressure measuring apparatus and a means of measuring transit time. The occluding cuff is placed on one arm of the user and transit time is measured to a fingertip on the other arm.

Systolic blood pressure can be calculated from the measurements of transit time, whilst a linear empirical equation, known, for example, from US 4,869,262 involving transit time and heart rate can be used to estimate diastolic blood pressure. In this way, calibration lines for both diastolic and systolic blood pressure can be determined.

Determining a linear relationship between transit time and blood pressure involves making at least two measurements of

transit time and blood pressure over a sufficiently large pressure range, for example, at least 20 mmHg. This means taking a measurement of transit time and blood pressure when the user is at rest, that is before any exercise has been carried out, and then again immediately after the user has exercised.

A drawback of this method of generating calibration data for the blood pressure monitoring apparatus is the need to perform significant exercise to obtain the calibration relationship of blood pressure with transit time. Many users are reluctant, for example, for reasons of health or laziness, to raise their blood pressure by means of exercise.

As an alternative, a method of producing calibration lines from a single measurement of blood pressure and transit time of a user at rest is known. This measurement establishes one point on the calibration line and the slope through this point is taken as an average slope obtained from a relatively extensive range of measurements for a large and wide sample of a population. For example, an average systolic slope is -0.61 mmHg/ms. The use of the average slope in place of a second calibration point gives relatively accurate calibration provided the user's pressure does not diverge far from the "at rest" value.

This single point measurement method is not considered to be very accurate for determining blood pressure during exercise as it is known that there is a significant variation within the population of individual values for the slope of blood pressure against transit time, For example, the slope will be affected by the size of the user's body.

It is therefore an object of the present invention to provide a means to overcome or minimise these problems such that the accuracy of a blood pressure monitoring apparatus based on transit time measurement calibrated when a user is at rest is improved.

According to the present invention there is provided a method of calibrating blood pressure measurement apparatus comprising the steps of:

measuring at least one blood pressure of a living body by pressure measuring means, and measuring a reference transit time, by timing means, of a blood pulse wave travelling along a blood vessel pathway from a heart of the living body to a region of the living body remote from the heart, the remote region being in a reference position, wherein the at least one blood pressure and reference transit time generate a first calibration data point;

moving the region of the body remote from the heart to a lowered position below the level of the heart and measuring a lowered position transit time of the blood pulse wave from the heart of the living body to the region of the living body remote from the heart by the timing means;

moving the region of the body remote from the heart to a raised position above the level of the heart and measuring a raised position transit time of the blood pulse wave from the heart of the living body to the region of the living body remote from the heart by the timing means;

calculating a blood pressure difference within the blood vessel between when the region of the body remote from the heart is in the lowered position and in the raised position;

calculating a transit time difference between the lowered position and raised position transit times; and

generating a second calibration data point data from the calculated blood pressure difference and transit time difference.

The reference position may be substantially at the same level as the heart.

The first and second calibration points may be joined together to generate a slope of a calibration line representing a linear relationship between blood pressure and transit time. The slope of the calibration line may allow a blood pressure value to be determined from a measured transit time measurement.

The calibration line representing the linear relationship between blood pressure and transit time of the living body may be generated without the need for the living body to exercise.

The lowered position of the region of the body remote from the heart may provide a second transit time and the raised position of the region of the body remote from the heart may provide a third transit time.

The at least one blood pressure measurement may be systolic and/or diastolic blood pressure measurement.

The pressure measuring means may comprise an occluding cuff.

The timing means may comprise means to detect an ECG signal from the heart, and preferably may comprise means to detect a trigger signal from the ECG signal.

The detection means may comprise chest contacts mounted either in a flexible vest belt or in the form of two separate self-adhesive contacts.

The detection means may comprise two hand contacts.

The timing means may comprise a means of detecting the arrival of a blood pulse wave at the region of the body remote from the heart, preferably by means of a photoplethysmograph.

The time taken from the trigger signal of the ECG signal to the detected arrival of a region of the blood pulse wave may determine the transit time.

The region of the blood pulse wave detected may be substantially half way up the blood pulse wave and/or substantially at the foot of the blood pulse wave.

The region of the body remote from the heart may be a fingertip, earlobe or toe.

The blood vessel pathway from the heart to the fingertip may comprise three segments relating to sections of the blood vessel pathway from the heart to a shoulder, from the shoulder along an upper arm to an elbow, and from the elbow along a forearm and hand to the fingertip.

The section of the blood vessel pathway from the heart to the shoulder may comprise a fraction about 1/6 of the full distance from the heart to the fingertip, the section of the blood vessel pathway from the shoulder to the elbow may comprise a fraction about 1/3 of the full distance from the heart to the fingertip, and the section of the blood vessel pathway from the elbow along the forearm and hand may comprise a fraction about 1/2 of the full distance from the heart to the fingertip.

The blood pressure difference, within the blood vessel pathway from the heart to the fingertip, between when the fingertip is in the raised and lowered positions may be calculated from a constant, relating to gravity and the density of blood, multiplied by a linear (vertical) distance between the fingertip in the raised and lowered positions multiplied by a sum of the fractional distance of the blood vessel pathway from the elbow to the hand and half of the fractional distance of the blood vessel pathway from the shoulder to the elbow.

The region of the body remote from the heart may be moved to the raised or lowered position by manual or mechanical means. The mechanical means may comprise a tilt table.

The region of the body remote from the heart may be raised or lowered relative to the level of the heart in a range from 1 to 30 cm, preferably about 20 cm.

The region of the body remote from the heart may be supported in position relative to the level of the heart.

For a better understanding of the present invention and to show more clearly how it may be carried into effect reference will now be made, by way of example, to the accompanying drawings in which:

Figure 1 is a diagram showing an ECG signal and blood pulse wave signal and measurements used to determine transit time in accordance with the present invention;

Figure 2 is a front view of an individual fitted with means to detect the ECG signal shown in Figure 1;

Figure 3 is a schematic of a fingertip of a user fitted with means to detect the arrival of the blood pulse wave shown in Figure 1;

Figure 4 is a block diagram of electronic circuitry contained within a blood pressure monitoring apparatus to be calibrated in accordance with the present invention;

Figure 5 is a series of side views of the user undergoing measurements in accordance with the present invention;

Figure 6 is a schematic of arterial routing in the arm of the user in the positions shown in Figure 5; and

Figure 7 is a diagram showing two calibration lines produced in accordance with the present invention.

The present invention concerns the measurement of transit times for pulse waves of blood within an artery to travel from the heart to a region of the body remote from the heart, and the use of such measurements, along with blood pressure measurements, to generate calibration lines for a blood pressure monitoring apparatus. Figures 1 to 4 show how the required measurements are obtained and processed.

Figure 1 shows how systolic 1 and diastolic 3 transit times are determined by measuring the time taken from an electronic trigger signal 5 of an R-wave of a ECG signal 7 to the arrival of portions of a blood pulse wave 9 detected at a region of a body remote from the heart, for example, a fingertip. The systolic transit time 1 is measured from the trigger signal 5 to a blood pulse wave arrival instant 11 half way up the leading edge of the detected pulse wave 9. The diastolic transit time 3 is measured from the trigger signal 5 to the foot 13 of the detected blood pulse wave 9.

The ECG signal 7 is picked up from two chest contacts 15, for example, mounted in a flexible chestbelt, which are attached to a user 17, as shown in Figure 2.

The arrival of the blood pulse wave at a user's fingertip is detected by means of a photoplethysmograph 19 attached to the user's fingertip 21 as shown in Figure 3. The photoplethysmograph 19 comprises a relatively simple and standard non-occluding cuff comprising an infra-red light emitting diode 23, powered by a charging current 24, and a photo-transistor 25. The photoplethysmograph 19 detects changes in blood perfusion in the fingertip 21. Light is transmitted through a capillary bed in the fingertip. As blood pulse waves fill the capillary bed the changes in

volume of the blood vessels modify the absorption, reflection and scattering of the light allowing successive blood pulse waves to be detected.

Figure 4 shows the electronic circuitry of a blood pressure measuring device 27. The ECG signal from the chest contacts 15 is amplified by an amplifier 29 and the high and low frequency components are removed by a filter circuit 31. The filtered signal is further processed electronically by a full-wave rectifier 33 and a double differentiator 35. The resulting analogue signal is presented to a microcontroller 37 where it is digitised and processed to remove extraneous components and extract an accurate timing trigger signal. Meanwhile the signal from the photoplethysmograph 19 is amplified by an amplifier 39 and the high and low frequency components are removed by a filter 41. This signal is then presented to the microcontroller 37 where it is digitised and processed to extract the times of arrival of the diastolic and systolic pressure thresholds. On each heart beat the microcontroller 37 calculates the diastolic and systolic transit times and uses these values, along with simultaneous measurements of diastolic and systolic blood pressure obtained using an occluding cuff (not shown) and entered via a keypad 43, to determine the calibration lines for a particular user.

Figure 5 shows an embodiment of some of the stages of a method in accordance with the present invention.

In Figure 5A the user 17 while seated, for example in front of a desk, has simultaneous measurements made of blood pressure, both systolic and diastolic, taken using an occluding cuff (not shown), and transit times, both diastolic and systolic, taken to a photoplethysmograph 19 on a fingertip on the opposite arm from that fitted with the occluding cuff. The arm fitted with the photoplethysmograph 19 is supported such that the forearm 45 and hand 47 are at substantially the same height 49 as the user's heart. This determines "at rest" points on the user's systolic and diastolic calibration lines.

The occluding cuff is then removed, and the arm attached to the photoplethysmograph 19 is lowered such that the forearm 45 rests on the desk, as shown in Figure 5B. The distance over which the arm is lowered is in a range from 1 to 30 cm, preferably 20 cm. Diastolic and systolic transit times are again measured. These will be referred to herein as TTdl (transit time diastolic lower) and TTsl (transit time systolic lower).

The arm attached to the photoplethysmograph 19 is then raised such that the forearm 45 is supported in a position

where the forearm 45 and hand 47 are a distance in the range from 1 to 30 cm, preferably 20 cm, higher than the heart, as shown in Figure 5C. Diastolic and systolic transit times are again measured. These will be referred to herein as TTdr (transit time diastolic raised) and TTsr (transit time systolic raised).

Because the blood pressure in most of the arm when down is higher, due to hydrostatic pressure, than when the arm is raised, TTdl and TTsl are shorter than TTdr and Ttsr respectively.

The effective hydrostatic pressure difference, which is the same for systolic and diastolic pressures, is estimated from the dimensions of the arm, the arterial routing within the arm, the distance moved by the arm between the lowered and raised positions and the specific gravity of blood. This pressure difference is converted to the standard units of blood pressure, mmHg, using the specific gravity of mercury.

With reference to Figure 6, to calculate an effective hydrostatic pressure increment when moving from the arm raised above the level of the heart to the arm lower than the level of the heart, the blood pulse wave path from heart 51 to fingertip is divided into three straight

segments a, b and c, where a, b and c are fractions of the total path. Typically a (heart 51 to shoulder 53) = 1/6, b (upper arm 55 from shoulder to elbow) = 1/3, and c (forearm 45 and hand 47) = 1/2.

The height or orientation of segment a does not change when the arm is moved, therefore segment a does not experience any change in pressure when the arm is moved. The hydrostatic pressure in the remaining segments, b and c, with respect to a pivot point in the shoulder 53 can be estimated as follows:-

For one segment, the average hydrostatic pressure, Ph(av) is:-

Ph(av) = K x length x height of mid-point of segment above pivot point

where K is a constant involving gravity (g) and the density of blood.

Effective hydrostatic pressure increase Ph(eff), arm down minus arm up is:-

$$
\begin{aligned}
Ph(eff) &= K[c(U+D) = bU/2 + bD/2] \\
&= K[c(U+D) = b(U+D)/2] \\
&= K(U+D)(c+b/2)
\end{aligned}
$$

Where U is the distance of the fingertip above the heart (typically 20 cm), D is the distance of the fingertip below the heart (typically 20 cm), c is 1/2 and b is 1/3.

Therefore for the figures shown hereinabove:-

Ph(eff) = K(27 cm blood) = K(21 mmHg).

Figure 7 shows a plot of systolic 57 and diastolic 59 calibration lines. The values of "at rest" systolic blood pressure against transit time and "at rest" diastolic blood pressure against transit time are shown as points 61 and 63 respectively.

A second point 65 on the systolic line 57 has been plotted for a value of transit time (TT) equating to the "at rest" systolic transit time minus the systolic transit time difference (Ttsr-TTsl), shown as ΔTTs 67, plotted against a value of blood pressure (BP) equating to the "at rest" blood pressure plus the calculated effective hydrostatic blood pressure increase (ΔP) 69. In conjunction with the systolic "at rest" point 61, this second point 65 gives the slope of the user's systolic calibration line 57.

A second point 73 on the diastolic line 59 has similarly been plotted for a value of transit time (TT) equating to the "at rest" diastolic transit time minus the diastolic

transit time difference (Ttdr-TTdl), shown as ΔTTd 75, plotted against a value of blood pressure (BP) equating to the "at rest" blood pressure plus the calculated effective hydrostatic blood pressure increase (ΔP) 69. In conjunction with the diastolic "at rest" point 63, this second point 73 gives the slope of the user's diastolic calibration line 59.

The calculations of effective hydrostatic blood pressure increase 69, difference in transit time 67, 75 and the calculation of the calibration lines are carried out by the microprocessor 37 of the blood pressure monitoring apparatus 27 shown in Figure 4.

Using these calibration lines 57, 59 the blood pressure monitoring apparatus is calibrated for the user, without the need for the user to undergo exercise. The transit time measuring process is relatively comfortable and silent and therefore facilitates 24 hour ambulatory monitoring. Measurements can be taken at any site on the body, for example, fingertip, earlobe or toe, where a photoplethysmograph gives a satisfactory signal, and which is sufficiently removed from the heart to give a relatively long transit time to enable accurate measurement to be obtained.

Measurement of the transit times for the user's systolic and diastolic blood pulse wave can be converted into an estimate of instantaneous systolic and diastolic blood pressure values using the calibration lines and the estimated blood pressures can be presented on a display (not shown).

Heart rate can be displayed in beats per minute from calculations made using measured beat-to-beat intervals. The blood pressure estimates, obtained on every heart beat, can be averaged over several beats, for example, 10 or 20, to remove short term cyclic variations which occur with most users, for example, due to breathing. These averaged values can be stored in the memory of the microcontroller 37, or in additional memory means (not shown), to give a recording of the user's blood pressures over an extended period such as 24 hours. Alternatively, the individual estimates of blood pressure are recorded to give a trace of the beat-to-beat variability of the user's blood pressure, providing valuable diagnostic information as to the health of the user's cardiovascular system. The recordings can be provided to a computer (not shown) for further analysis and archiving.

A heart rate monitoring apparatus calibrated in accordance with the present invention can be used to collect

diagnostic information about the user's cardiovascular system. Transit times can be measure to other areas of the body, for example to an earlobe or toe, and compared with the transit time to the fingertip. Any change in measured transit time, not accounted for by a blood pressure change, could indicate a change in the properties of the relevant cardiovascular route.

The calibration procedure as described hereinabove relates to the changing of the hydrostatic pressure within the arteries of an arm by the raising and lowering of that arm as in most cases this will be the most convenient method for the user. However, it should be understood that there are other ways of mechanically changing the hydrostatic pressure within a limb which can be used for the method of producing the calibration lines and calibrating a blood pressure monitor. For example, a tilt table can be used to alter the hydrostatic pressure within the arteries of an arm, or within the arteries in a leg from the heart to a toe.

It should also be understood that although the ECG signal is described hereinabove as being detected by two chest contacts in a flexible chest belt, the chest contacts could be in the form of separate self-adhesive patches or detection can be carried out using two hand contacts.

CLAIMS

1. A method of calibrating blood pressure measurement apparatus comprising the steps of:

measuring at least one blood pressure of a living body by pressure measuring means, and measuring a reference transit time, by timing means, of a blood pulse wave travelling along a blood vessel pathway from a heart of the living body to a region of the living body remote from the heart, the remote region being in a reference position, wherein the at least one blood pressure and reference transit time generate a first calibration data point;

moving the region of the body remote from the heart to a lowered position below the level of the heart and measuring a lowered position transit time of the blood pulse wave from the heart of the living body to the region of the living body remote from the heart by the timing means;

moving the region of the body remote from the heart to a raised position above the level of the heart and measuring a raised position transit time of the blood pulse wave from the heart of the living body to the region of the living body remote from the heart by the timing means;

calculating a blood pressure difference within the blood vessel between when the region of the body remote from the heart is in the lowered position and in the raised position;

calculating a transit time difference between the lowered position and raised position transit times; and

generating a second calibration data point from the calculated blood pressure difference and transit time difference.

2. A method as claimed in claim 1, wherein the reference position is substantially at the same level as the heart.

3. A method as claimed in claim 1 or 2, wherein the first and second calibration points are joined together to generate a slope of a calibration line representing a linear relationship between blood pressure and transit time.

4. A method as claimed in claim 3, wherein the slope of the calibration line allows a blood pressure value to be determined from a measured transit time measurement.

5. A method as claimed in claim 3 or 4, wherein the calibration line representing the linear relationship between blood pressure and transit time of the living body is generated without the need for the living body to exercise.

6. A method as claimed in any preceding claim, wherein the lowered position of the region of the body remote from the heart provides a second transit time.

7. A method as claimed in any preceding claim, wherein the raised position of the region of the body remote from the heart provides a third transit time.

8. A method as claimed in any preceding claim, wherein the at least one blood pressure measurement is systolic blood pressure measurement.

9. A method as claimed in any preceding claim, wherein the at least one blood pressure measurement is diastolic blood pressure measurement.

10. A method as claimed in any preceding claim, wherein the pressure measuring means comprises an occluding cuff.

11. A method as claimed in any preceding claim, wherein the timing means comprises means to detect an ECG signal from the heart.

12. A method as claimed in claim 11, wherein the timing means comprises means to detect a trigger signal from the ECG signal.

13. A method as claimed in claim 11 or 12, wherein the detection means comprises chest contacts mounted in a flexible chest belt.

14. A method as claimed in claim 11 or 12, wherein the detection means comprises chest contacts in the form of two separate self-adhesive contacts.

15. A method as claimed in claim 11 or 12, wherein the detection means comprises two hand contacts.

16. A method as claimed in any preceding claim, wherein the timing means comprises a means of detecting the arrival of a blood pulse wave at the region of the body remote from the heart.

17. A method as claimed in claim 16, wherein the means of detecting the arrival of a blood pulse wave is by means of a photoplethysmograph.

18. A method as claimed in claim 16 or 17, wherein the time taken from the trigger signal of the ECG signal to the detected arrival of a region of the blood pulse wave determines the transit time.

19. A method as claimed in claim 18, wherein the region of the blood pulse wave detected is substantially half way up the blood pulse wave.

20. A method as claimed in claim 18 or 19, wherein the region of the blood pulse wave detected is substantially at the foot of the blood pulse wave.

21. A method as claimed in any preceding claim, wherein the region of the body remote from the heart is a fingertip.

22. A method as claimed in any one of claims 1 to 20, wherein the region of the body remote from the heart is an earlobe.

23. A method as claimed in any one of claims 1 to 20, wherein the region of the body remote from the heart is a toe.

24. A method as claimed in any one of claims 1 to 21, wherein the blood vessel pathway from the heart to the fingertip comprises three segments relating to sections of the blood vessel pathway from the heart to a shoulder, from the shoulder along an upper arm to an elbow, and from the elbow along a forearm and hand to the fingertip.

25. A method as claimed in claim 24, wherein the section of the blood vessel pathway from the heart to the shoulder comprises a fraction about 1/6 of the full distance from the heart to the fingertip, the section of the blood vessel pathway from the shoulder to the elbow comprises a fraction about 1/3 of the full distance from the heart to the fingertip, and the section of the blood vessel pathway from the elbow along the forearm and hand comprises a fraction about 1/2 of the full distance from the heart to the fingertip.

26. A method as claimed in claim 24 or 25, wherein the blood pressure difference, within the blood vessel pathway from the heart to the fingertip, between when the fingertip is in the raised and lowered positions is calculated from

a constant, relating to gravity and the density of blood, multiplied by a linear (vertical) distance between the fingertip in the raised and lowered positions multiplied by a sum of the fractional distance of the blood vessel pathway from the elbow to the hand and half of the fractional distance of the blood vessel pathway from the shoulder to the elbow.

27. A method as claimed in any preceding claim, wherein the region of the body remote from the heart is moved to the raised or lowered position by manual means.

27. A method as claimed in any one of claims 1 to 26, wherein the region of the body remote from the heart is moved to the raised or lowered position by mechanical means.

28. A method as claimed in claim 27, wherein the mechanical means comprises a tilt table.

29. A method as claimed in any preceding claim, wherein the region of the body remote from the heart is raised or lowered relative to the level of the heart in a range from 1 to 30 cm.

30. A method as claimed in claim 29, wherein the region of the body remote from the heart is raised or lowered relative to the level of the heart by about 20 cm.

31. A method as claimed in any preceding claim, wherein the region of the body remote from the heart is supported in position relative to the level of the heart.

32. A method of calibrating blood pressure measurement apparatus substantially as hereinbefore described, with reference to the accompanying drawings.

Application No: GB 0223381.5
Claims searched: 1-31
Examiner: Hayley Yates
Date of search: 11 February 2004

Patents Act 1977 : Search Report under Section 17

Documents considered to be relevant:

Category	Relevant to claims	Identity of document and passage or figure of particular relevance	
A		US 4718428	Russell; see figure 1A
A		US 4562843	Djordjevich et al; see figure 5
A		US 6475153 B1	Khair et al; see column 3 lines 26-45
A		US 6511436 B1	Asmar; see column 2 lines 14-40
A		US 2002/0055672 A1	Zhang; see [0048 - 0051
A		EP 0181067 A3	Pulse Time Products Limited

Categories:

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
&	Member of the same patent family	E	Patent document published on or after, but with priority date earlier than, the filing date of this application.

Field of Search:

Search of GB, EP, WO & US patent documents classified in the following areas of the UKC^{W}:

A5K, G1A, G1N

Worldwide search of patent documents classified in the following areas of the IPC^{7}:

A61B

The following online and other databases have been used in the preparation of this search report:

JAPIO, WPI, EPODOC